

Diffractive production of charm quark/antiquark pairs at RHIC and LHC

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Abstract.

We have discussed single and central diffractive production of $c\bar{c}$ pairs in the Ingelman-Schlein model. In these calculations we have included diffractive parton distributions obtained by the H1 collaboration at HERA and absorption effects neglected in some early calculations in the literature. The absorption effects which are responsible for the naive Regge factorization breaking cause that the cross section for diffractive processes is much smaller than that for the fully inclusive case, but could be measured at RHIC and LHC by imposing special condition on rapidity gaps. We discuss also different approaches to diffractive production of heavy quark/antiquark [1, 2, 3]. The particular mechanism is similar to the diffractive dissociation of virtual photons into quarks, which drives diffractive deep inelastic production of charm in the low-mass diffraction, or large β -region.

Keywords: Diffractive production, heavy quarks, pomeron

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INTRODUCTION

In this presentation we discuss diffractive processes (single and central) in the framework of Ingelman-Schlein model corrected for absorption. The formalism and more details has been shown and discussed elsewhere [4]. Such a model was used in the estimation of several diffractive processes [5, 6, 7, 8]. The absorption corrections are necessary to understand a huge Regge-factorization breaking observed in single and central production at Tevatron. We mention also the QCD mechanism of diffractive dissociation of gluons into heavy quark pairs. However, the associated formalism and our results (in progress) will be discussed elsewhere [9].

A SKETCH OF FORMALISM

The mechanisms of the diffractive production of heavy quarks ($c\bar{c}$) discussed here are shown in Figs.1,2.

In the following we apply the Ingelman and Schlein approach. In this approach one assumes that the Pomeron has a well defined partonic structure, and that the hard process takes place in a Pomeron–proton or proton–Pomeron (single diffraction) or Pomeron–Pomeron (central diffraction) processes. In this approach corresponding differential

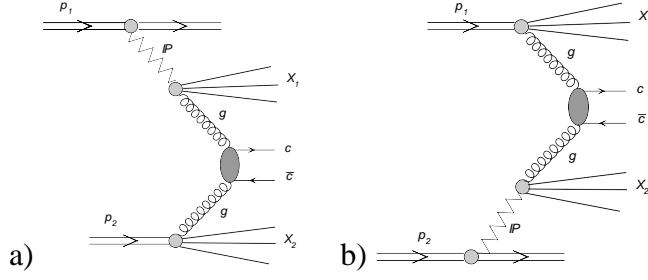


FIGURE 1. The mechanism of single-diffractive production of $c\bar{c}$.

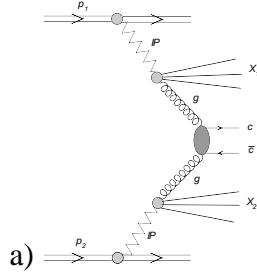


FIGURE 2. The mechanism of central-diffractive production of dileptons.

cross sections can be written as

$$\frac{d\sigma_{SD}}{dy_1 dy_2 dp_t^2} = K \frac{|M|^2}{16\pi^2 \hat{s}^2} \left[\left(x_1 q_f^D(x_1, \mu^2) x_2 \bar{q}_f(x_2, \mu^2) \right) + \left(x_1 \bar{q}_f^D(x_1, \mu^2) x_2 q_f(x_2, \mu^2) \right) \right], \quad (1)$$

$$\frac{d\sigma_{CD}}{dy_1 dy_2 dp_t^2} = K \frac{|M|^2}{16\pi^2 \hat{s}^2} \left[\left(x_1 q_f^D(x_1, \mu^2) x_2 \bar{q}_f^D(x_2, \mu^2) \right) + \left(x_1 \bar{q}_f^D(x_1, \mu^2) x_2 q_f^D(x_2, \mu^2) \right) \right] \quad (2)$$

for single-diffractive and central-diffractive production, respectively.

The 'diffractive' quark distribution of flavour f can be obtained by a convolution of the flux of Pomerons $f_{\mathbf{P}}(x_{\mathbf{P}})$ and the parton distribution in the Pomeron $q_{f/\mathbf{P}}(\beta, \mu^2)$:

$$q_f^D(x, \mu^2) = \int dx_{\mathbf{P}} d\beta \delta(x - x_{\mathbf{P}}\beta) q_{f/\mathbf{P}}(\beta, \mu^2) f_{\mathbf{P}}(x_{\mathbf{P}}) = \int_x^1 \frac{dx_{\mathbf{P}}}{x_{\mathbf{P}}} f_{\mathbf{P}}(x_{\mathbf{P}}) q_{f/\mathbf{P}}\left(\frac{x}{x_{\mathbf{P}}}, \mu^2\right). \quad (3)$$

The flux of Pomerons $f_{\mathbf{P}}(x_{\mathbf{P}})$ enters in the form integrated over four-momentum transfer

$$f_{\mathbf{P}}(x_{\mathbf{P}}) = \int_{t_{min}}^{t_{max}} dt f(x_{\mathbf{P}}, t), \quad (4)$$

with t_{min}, t_{max} being kinematic boundaries.

Both pomeron flux factors $f_{\mathbf{P}}(x_{\mathbf{P}}, t)$ as well as quark/antiquark distributions in the pomeron were taken from the H1 collaboration analysis of diffractive structure function and diffractive dijets at HERA [8]. The factorization scale for diffractive parton distributions is taken as $\mu^2 = \hat{s}$.

In Ref.[9] we shall study in detail mechanism of diffractive dissociation of gluons into heavy quark pairs presented in Fig.3. There we shall present relevant amplitudes, calculate relevant differential cross sections and compare to the Ingelman-Schlein model discussed here.

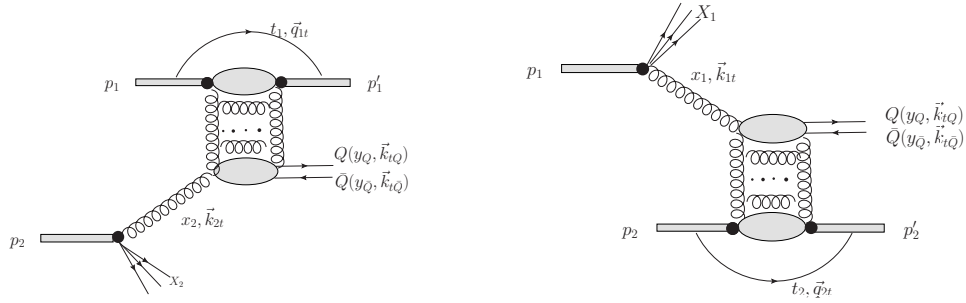


FIGURE 3.

RESULTS

In Fig.4 we show transverse momentum distributions of charm quarks (or antiquarks). The distribution for single diffractive component is smaller than that for the inclusive gluon-gluon fusion by almost 2 orders of magnitude. Our results include gap survival factor [4]. The cross section for central diffractive component is smaller by additional order of magnitude.

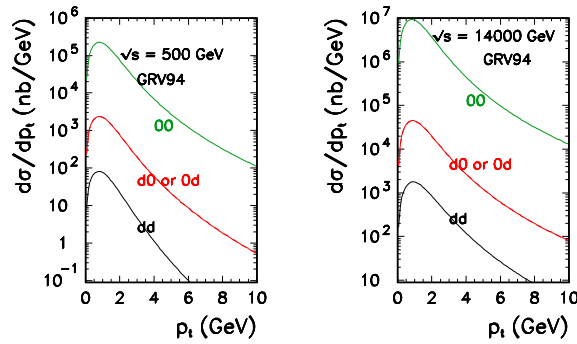


FIGURE 4. Transverse momentum distribution of c quarks (antiquarks) for RHIC energy $\sqrt{s} = 500$ GeV (left panel) and for LHC energy $\sqrt{s} = 14$ TeV (right panel) for the GRV94 gluon distributions. The result for single diffractive (0d or d0), central diffractive (dd) mechanisms are compared with that for the standard gluon-gluon fusion (00).

In Fig.5 we show distributions in quark (antiquark) rapidity. We show separately contributions of two different single-diffractive components (which give the same distributions in transverse momentum) and the contribution of central-diffractive component in Fig.4. When added together the single-diffractive components produce a distribution in rapidity similar in shape to that for the standard inclusive case.

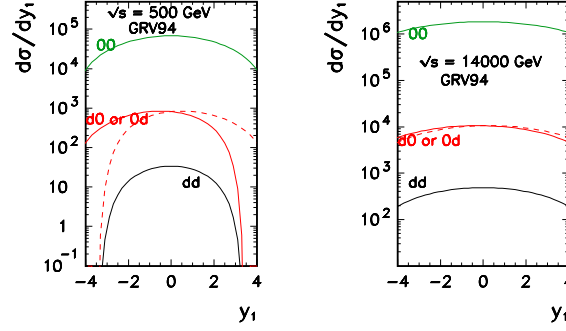


FIGURE 5. Rapidity distribution of c quarks (antiquarks) for RHIC energy $\sqrt{s} = 500$ GeV (left panel) and for LHC energy $\sqrt{s} = 14$ TeV (right panel) for the GRV94 gluon distributions. The result for single diffractive (0d or d0), central diffractive (dd) mechanisms is compared with that for the standard gluon-gluon fusion (00).

CONCLUSIONS

The cross section for single and central diffraction is rather small compared to the dominant gluon-gluon fusion component. However, a very specific final state (smaller multiplicity, forward protons) should allow its identification by imposing special conditions on the one-side (single-diffractive process) and both-side (central diffractive process) rapidity gaps. We hope that such an analysis is possible at LHC. Special care should be devoted to the observation of the exclusive $c\bar{c}$ production, i.e. the process $pp \rightarrow ppc\bar{c}$. Without a special analysis of the final state multiplicity the exclusive $c\bar{c}$ production may look like an inclusive central diffraction [4]. We have started detailed analysis of diffractive dissociation of gluons into $c\bar{c}$ pairs as a competitive process to the one discussed here.

REFERENCES

1. Alves, Levin and Santoro, Phys. Rev. D**55**, 2683 (1997).
2. Yuan and Chao, Phys. Rev. D**60**, 094012 (1999).
3. B.Z. Kopeliovich, I.K. Potashnikova, Ivan Schmidt, A.V.Tarasov, Phys. Rev. D**76** (2007) 034019.
4. M. Łuszczak, R. Maciula and A. Szczurek, Phys. Rev. D**84** (2011) 114018.
5. G. Ingelman, P.E. Schlein, Phys.Lett.**B152** (1985) 256.
6. A. Berera, J.C. Collins, Nucl. Phys. B**474** (1996) 183;
R.J.M. Covelan and M.S. Soares, Phys. Rev. D**67** (2003) 077504.
7. M.V.T. Machado, Phys. Rev. D**76** (2007) 054006.
8. A. Aktas *et al.* [H1 Collaboration], Eur. Phys. J. C **48** (2006) 715.
9. M. Łuszczak, W. Schäfer and A. Szczurek, a paper in preparation.